GRAZING, ECOLOGICAL CONDITION AND BIODIVERSITY IN RIPARIAN RIVER RED GUM FORESTS IN SOUTH-EASTERN AUSTRALIA

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The ecological condition of riparian habitats and the biodiversity of terrestrial birds, wetland frogs and herbaceous plants were surveyed in river red gum habitats on the Murrumbidgee and Murray Rivers. Sites were classified according to the intensity of grazing by domestic livestock: ungrazed; low grazing (<5 DSE/ha/annum); and high grazing (>5 DSE/ha/annum). Declines in the ecological condition of riparian habitats and loss of biodiversity of birds, frogs and plants were clearly associated with increased grazing intensity in river red gum habitats. Riparian condition differed significantly between all three levels of grazing, while bird, frog and plant communities differed significantly between high and low grazing intensities. Loss of woodland-dependent and threatened species of birds, fewer occurrences of tadpoles and the loss of several functional groups of native plants were also related to increases in grazing intensity. Exotic grasses were more abundant in low grazed sites than in ungrazed sites. While it is clear that grazing has had significant impacts on riparian function and biodiversity, it is not clear whether these impacts can be reversed to fully restore riparian river red gum habitats. To achieve full restoration of riparian function and biodiversity may require not only fencing to exclude stock or significantly reduce stocking rates, but also replanting of trees, shrubs and understorey, as well as on-going control of exotic species and restoration of more natural flooding regimes.

Keywords: Riparian grazing, birds, plants, frogs, ecological condition

RIPARIAN habitats are at the interface between terrestrial and aquatic ecosystems. They are critical components of the landscape, supporting high levels of biodiversity and having significant effects on material fluxes across terrestrial and riverine boundaries (Naiman & Decamps 1997).

A recent assessment of riparian river red gum habitats in south-eastern Australia concluded that average riparian condition was either degraded or fair with no riparian areas in good or near pristine condition (Sattler & Creighton 2002). Grazing was identified as a major threatening process for the majority of these riparian areas (Sattler & Creighton 2002).

The impacts of grazing by cattle on riparian systems have been reviewed by numerous authors (e.g. Fleischner 1994; Trimble & Mendel 1995; Belsky et al. 1999). They have concluded that grazing generally has significant negative impacts on riparian function and biodiversity. The majority of work has been carried out in the western United States, and experimental studies have mostly focussed on recovery from past heavy grazing (Belsky et al. 1999), and involve comparisons of relatively small plots (Fleischner 1994). Most of these studies have also been severely limited by weak experimental designs (Larsen et al. 1998; Sarr 2002). While there has been extensive work on the ecological impacts of grazing in Australian rangelands (e.g. Wilson & Harrington 1984; Landsberg et al. 2003) and grasslands (e.g. Moore 1970; Garden et al. 2000; McIvor 2002), there has been little work in riparian ecosystems. There is clearly a need to understand the impacts of grazing on riparian ecosystems at large spatial scales in Australia.

Given the difficulties with conducting experimental studies of grazing at large spatial scales, we decided to study how riparian condition and biodiversity vary with grazing regimes at the landscape scale. Condition refers to the degree to which human-altered ecosystems diverge from local semi-natural ecosystems in their ability to support a community of organisms and perform ecological functions (c.f. Karr 1999). In previous studies we have examined relationships between grazing impacts and riparian condition, terrestrial bird communities, wetland frog communities and herbaceous plant communities (Jansen & Robertson 2001a, 2001b; Jansen & Healey 2003; Jansen & Robertson submitted). In this paper we aim to bring together the results from these studies to examine the overall impacts of grazing on riparian zone function and biodiversity in river red gum forests of south-eastern Australia.

METHODS

Detailed site descriptions and methods can be found in Jansen & Robertson (2001a; 2001b), Jansen & Healey (2003) and Jansen & Robertson (submitted). Here we give a brief overview of the study region and the methodology.

Study region

The study region comprised a 620 km section between Gundagai and Hay in the middle reaches of the Murrumbidgee River, and additional sites in Millewa Forest near Mathoura (Fig. 1). These sites in Millewa Forest were 'Reference sites' - within a large continuous block of forest and minimally impacted by logging and grazing (although impacted to some extent by these factors in the past). The region is relatively flat, with only a small change in elevation from east to west (≈100 m), and the floodplain varies in width from hundreds of metres to several kilometres.

The area has a temperate climate with hot, dry summers (average maximum 31.2°C in January at Wagga Wagga; Bureau of Meteorology 2004) and cold, damp winters (average maximum 12.5°C in July at Wagga Wagga; Bureau of Meteorology 2004). Average annual rainfall is 585 mm at Wagga Wagga and 443 mm at Mathoura but varies from 714 mm at Gundagai at the eastern edge of the study area to 366 mm at Hay on the western edge of

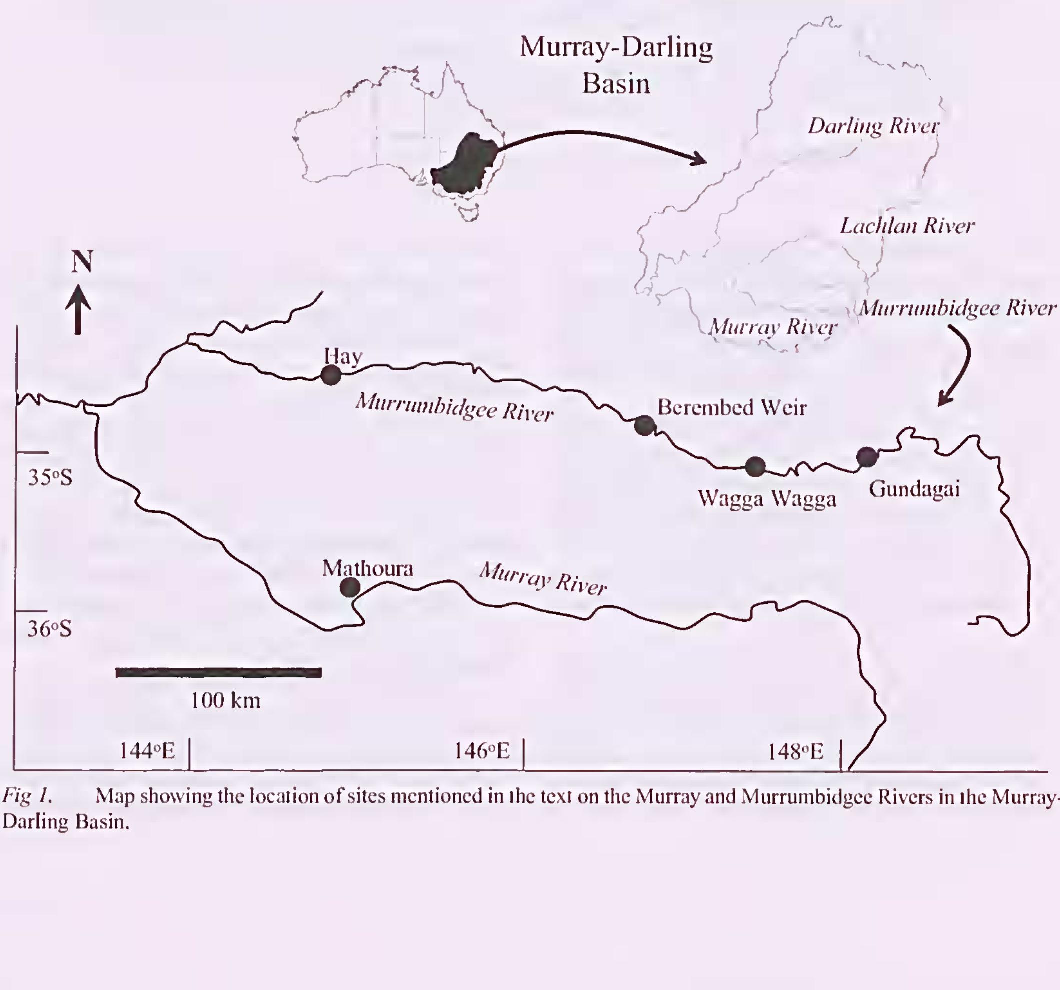

Fig 1. Map showing the location of sites mentioned in the text on the Murray and Murrumbidgee Rivers in the Murray-Darling Basin.

the study area (Fig. 1; Bureau of Meteorology 2004).

The floodplain vegetation is dominated by the river red gum *Eucalyptus camaldulensis* Dehnh. which defines the limits of flooding in the area. The region has been settled since the 1830s, has been extensively cropped and grazed over the last 150 years, and is now the primary agricultural region of Australia (Crabb 1997). Floodplain habitats have been highly modified at local and regional scales by altered flooding regimes, clearing, grazing by livestock and the introduction of exotic plant species (Margules & Partners Pty Ltd et al. 1990).

Grazing intensity

Sites sampled were located on private land, in State Forests, in Travelling Stock Reserves and in other reserves (Jansen & Robertson 2001a). Most sites were grazed by cattle, some by sheep, and a few by mixed herds of sheep and cattle. Interviews were conducted with farmers to determine stocking rates in riparian paddocks on private properties (for details see Jansen & Robertson 2001a). All stocking rates were expressed as dry sheep equivalents per hectare per annum (DSE/ha/annum; McLaren 1997). Sites were classified according to grazing intensity: ungrazed; low grazing (<5 DSE/ha/annum); and high grazing (>5 DSE/ha/annum). All grazed State Forest sites were classified as low grazing, based on information from the leaseholders. Most Travelling Stock Reserves were also classified as low grazing, while a few were classified as high grazing, based on evidence from cowpat counts in transects in the riparian zone (Jansen & Robertson 2001a). Other reserve sites were ungrazed but all had been grazed in the past (between 5 and 30 years prior to this study).

Riparian condition

Riparian condition was sampled in early summer of 1997-98 at 142 sites on the Murrumbidgee River between Gundagai and Hay, and at four sites in Millewa Forest near Mathoura. Riparian condition was scored using the Rapid Appraisal of Riparian Condition (RARC) on a scale of 0-50, with 50 indicating best condition, according to the method outlined in Jansen et al. (2004). This method scores a number of indicators of riparian zone function, groups them into five categories (habitat continuity and extent, cover and structural complexity of vegetation, quantities of leaf litter and woody debris, the amount of native vegetation. and features such as reeds and regeneration of native trees and shrubs). Each category is scored out of 10, and then the results are summed to obtain a score out of 50. Sites sampled were 1 km long reaches of the river; detailed methods are given in Jansen & Robertson (2001a).

Terrestrial birds

Birds were sampled using point count surveys at 46 sites on the Murrumbidgee River and four sites in Millewa Forest. At each site, three point count stations situated 100 m from the riverbank and separated by at least 200 m were surveyed in the morning in each of three seasons (Autumn 1998, Spring 1998 and Summer 1999). All birds seen and heard within 100 m in a 5 minute period were recorded at each point count station. For details of sampling and analysis, see Jansen & Robertson (2001b). In all analyses, birds flying overhead and aerial foragers (e.g. raptors and swallows) were excluded, as were water- and wetland-dependent species, since these were not considered to be censused accurately using point counts. Counts of individual species were summed across the three point counts at each site, and across the three seasons in which counts were made, to give a total count per site for each species.

Wetland frogs

Frogs were sampled using call surveys and searches, and tadpoles were sampled using sweep nets at 26 wetlands along the Murrumbidgee River in early summer of 1998 and 1999. Twenty-five wetlands were surveyed in 1998, 18 were resurveyed in 1999 (the remainder were dry) and one additional wetland was surveyed in 1999 (for details see Jansen & Healey 2003). Wetlands ranged from 40 to 9500 m in perimeter and in frequency of flooding from annually to much less frequently. Most of the wetlands were flooded from the river in 1998, many dried out subsequently, and some refilled with rainfall in 1999. At each wetland the following survey methods were used: (a) 10 minute night-time searches along the water's edge (two at wetlands <100 m in perimeter, four at wetlands 100-500 m in perimeter and 6-8 at larger wetlands); (b) 5 minute night-time counts of calling frogs (one at wetlands <100 m in perimeter, and two at larger wetlands); and (c) three 30 second day-time sweeps for tadpoles in each wetland microhabitat. Tadpoles were identified to genus, while adult frogs were identified to species. The results from all sampling strategies were combined to provide data on presence/absence of each species of frog and genus of tadpoles at each wetland over both years.

Herbaceous plants

Herbaceous plants were surveyed at 34 sites on the Murrumbidgee River in late spring – early summer of 1998. At each site, plants were surveyed along three 100 m transects perpendicular to the river, and approximately 200 m apart. A 0.25 m^2 quadrat was initially placed on the river bank where vegetation first appeared, then at 10 m intervals away from the river, for a total of 10 quadrats on each transect. Within each quadrat, floristic data (presence/absence of all non-woody plants) were recorded. Plant species were identified using Harden (2000-2002). A few taxa were only identified to genus when two species were difficult to distinguish in the field (e.g. *Vulpia* spp., *Hordeum* spp.) and a few specimens lacking flowering parts were also only identified to genus. Frequency data for each plant species were collated for the 30 quadrats surveyed at each site.

Confounding factors

The climate becomes increasingly arid with distance downstream along the Murrumbidgee River, and consequently stocking rates have probably historically declined with distance downstream (as they do today; Jansen & Robertson 2001a). There are also biogeographic shifts in the plant and animal communities with distance downstream. River regulation has also altered the seasonality and extent of flooding, particularly in the upstream reaches of the Murrumbidgee River above Berembed Weir (Ebsary 1994; Page et al. 2005). This could affect riparian plant communities, which often respond strongly to changes in hydrology (e.g. Gurnell et al. 2000; Hupp 2000), and wetland frog communities, which may be influenced by wetland flooding parameters (e.g. Snodgrass et al. 2000).

Analyses of the community data showed that plant and bird communities, but not frog communities, varied along the length of the river (Jansen & Robertson 2001b; Jansen & Healey 2003; Jansen & Robertson submitted). Thus we had to remove these effects in order to detect differences in plant and animal communities as a result of grazing. For the bird community analyses, we excluded the ten species that were confined to either the western end of the Murrumbidgee River or to the eastern end and/or the Murray River. All other species used in the analyses of grazing effects were widespread throughout the region (pers. obs.), making confounding effects unlikely. For the frog community analyses, there was no variation along the length of the river, so grazing effects were examined directly. For the plant community analyses, the river was divided into regions upstream and downstream of Berembed Weir to reduce the confounding effects of both biogeographic differences and altered flow regimes, and analyses of grazing effects were conducted separately for each region.

Data analyses

Table 1 shows the number of sites at each level of grazing intensity for each dataset.

Univariate data were analysed using General Linear Models (GLM) in SPSS (SPSS Inc. 1999) while community data were analysed using Analysis of Similarities (ANOSIM; Clarke 1993) in PRIMER (Clarke & Gorley 2001). Non-metric multi-dimensional scaling (MDS) in PRIMER was used to graphically illustrate differences between communities subject to different grazing regimes. Bird community data were square-root transformed before analysis. Similarities were calculated using the Bray-Curtis metric (Clarke & Warwick 1994).

To examine bird community changes in more detail, we classified bird species according to whether they were woodland-dependent and threatened or declining following Reid (1999). Total abundances and numbers of species in these groups were examined in relation to grazing effects using GLM.

	Ungrazed	Low grazing	High grazing
RARC	10	88	48
Birds	6	23	21
Frogs	-	14	12
Plants	5	14	15

Table 1. Number of sites at each level of grazing intensity for each survey (RARC=Rapid Appraisal of Riparian Condition - see Methods).

To examine plant community changes in more detail, we classified plant species according to functional groups (by growth form - grass, forb, sedge/reed, geophyte, fern; by life history - annual/biennial, perennial; and by height – small <5 cm, medium 5-30 cm, tall >30 cm) and as natives *vs* exotics using Harden (2000-2002). Total abundances and numbers of species in these groups were examined using GLM in relation to grazing effects within each region (above and below Berembed Weir as for the community data).

RESULTS

Riparian condition

Riparian condition declined significantly with increasing grazing intensity (Fig. 2; $F_{2,143}$= 44.04, p<0.0001).

Birds

A total of 64 species of terrestrial birds were recorded in the surveys. Of these, 54 were widespread species. Widespread bird communities differed significantly according to grazing intensity (Fig. 3; ANOSIM Global R=0.217, p<0.001). Pairwise tests showed that high grazed sites had significantly different bird communities to low grazed sites

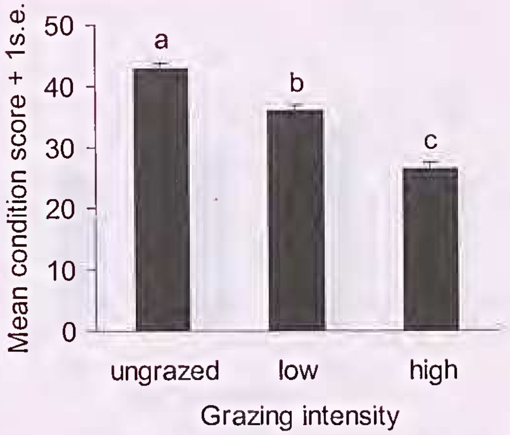

Fig 2. Mean (+1 s.e.) condition scores (measured using the Rapid Appraisal of Riparian Condition) at sites differing in grazing intensity on the Murray and Murrumbidgee Rivers. Letters indicate significant differences.

(p=0.001) and ungrazed sites (p=0.002) but the latter two were not significantly different (p=0.098). The number of species (Fig. 4A) and the number of individuals (Fig. 4B) of woodland-dependent birds were both significantly lower in high grazed sites than either ungrazed or low grazed sites, which were similar (Number of species $F_{2,47}$=4.26, p=0.0199; Number of individuals $F_{2,47}$=9.92, p=0.0003). The same pattern was evident for the number of individuals of threatened and declining species of birds (Fig. 5), although there was no significant difference

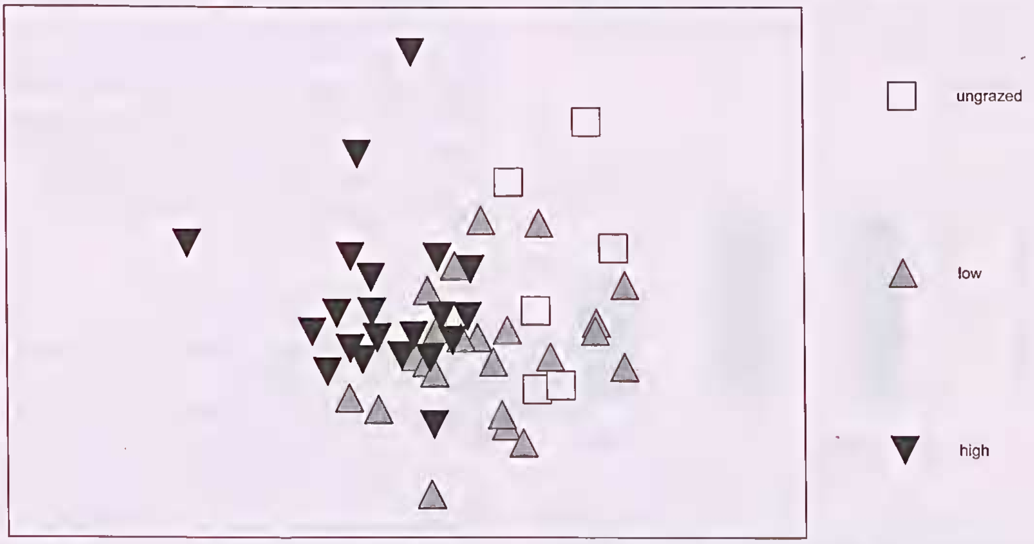

Fig 3. Non-metric multidimensional scaling plot of bird communities at 50 sites on the Murray and Murrumbidgee Rivers according to grazing intensity. Stress=0.21.

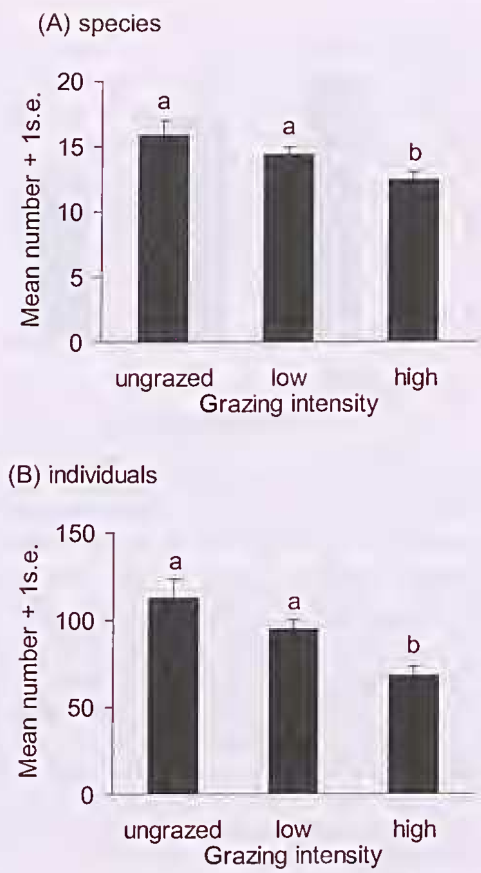

Fig 4. Mean (+1 s.e.) number of woodland-dependent bird species (A) and individuals (B) at sites differing in grazing intensity on the Murray and Murrumbidgee Rivers. Letters indicate significant differences.

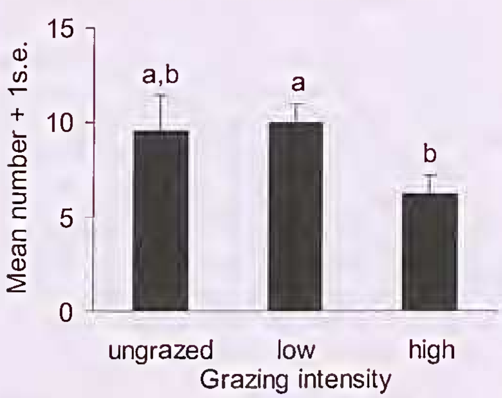

Fig 5. Mean (+1 s.e.) number of individuals of threatened and declining species of birds at sites differing in grazing intensity on the Murray and Murrumbidgee Rivers. Letters indicate significant differences.

between high grazed and ungrazed sites ($F_{2,47}$=3.77, p=0.0302).

Frogs

A total of six species of frogs and three genera of tadpoles were identified in the surveys. Frog communities differed significantly according to grazing intensity (Fig. 6; ANOSIM Global R=0.163, p=0.004). *Crinia* tadpoles only occurred at low grazed wetlands, and *Limnodynastes* tadpoles were significantly more likely to occur at low grazed wetlands than high grazed wetlands (χ^2_1=10.54, p=0.002).

Plants

A total of 126 species of herbaceous plants were identified in the surveys; of these, 53% were exotic species. Plant communities upstream of Berembed Weir differed significantly between high and low grazed sites (Global R=0.314, p=0.009) but downstream of Berembed Weir plant communities did not differ significantly between low grazed and ungrazed sites (Fig. 7). Native medium-height annual grasses, tall perennial forbs and small perennial sedges were all significantly more frequent in low grazed sites than high grazed sites upstream of Berembed Weir (Fig. 8A; grasses: $F_{1,20}$=6.80, p=0.017, forbs: $F_{1,20}$=5.35, p=0.031, sedges: $F_{1,20}$=4.33, p=0.05), but did not differ significantly between ungrazed and low grazed sites downstream of Berembed Weir. Exotic annual grasses were significantly less frequent in ungrazed sites than low grazed sites downstream of Berembed Weir (Fig. 8B; $F_{1,10}$=4.99, p=0.0495) but did not differ significantly between low and high grazed sites upstream of Berembed Weir.

DISCUSSION

Declines in the ecological condition of riparian habitats and loss of biodiversity of birds, frogs and plants were clearly associated with increased grazing intensity in river red gum habitats. Riparian condition differed between all three levels of grazing intensity while bird, frog and plant communities differed between high and low grazing intensity sites. Loss of woodland-dependent and threatened species of birds, fewer occurrences of tadpoles and the loss of several functional groups of

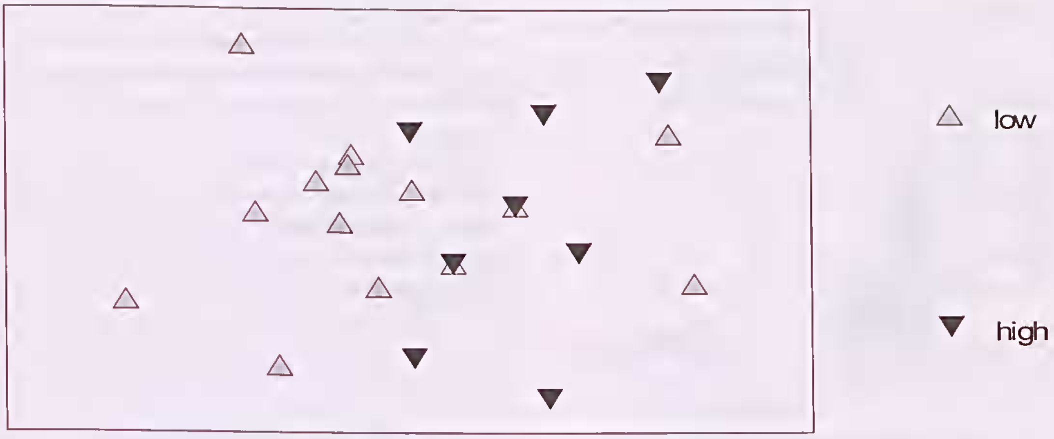

Fig 6. Non-metric multidimensional scaling plot of frog communities at 26 sites on the Murrumbidgee River according to grazing intensity. Stress=0.21.

native plants were also related to increases in grazing intensity. Exotic grasses were more abundant in low grazed sites than in ungrazed sites.

While few differences were found between ungrazed and low grazed sites, this is not surprising given the small number of ungrazed sites and their prior history of grazing (all 'ungrazed' sites had been grazed in the past). Thus while there was little clear evidence of significant impacts of grazing on biodiversity at low stocking rates (<5 DSE/ha/annum), this is most likely due to a lack of reference sites in near pristine condition. This is borne out by the fact that riparian condition was significantly higher in the few ungrazed sites that were found than in the low grazed sites. It is likely that riparian condition measured using the RARC can recover more quickly from past grazing than any direct measures of biodiversity.

While grazing impacts on riparian condition and biodiversity were clearly evident, it is difficult to separate out the effects of past grazing history, and associated land management practices, from current grazing intensity. These are most likely highly correlated, and our measures of condition and biodiversity may respond differently to each factor. For

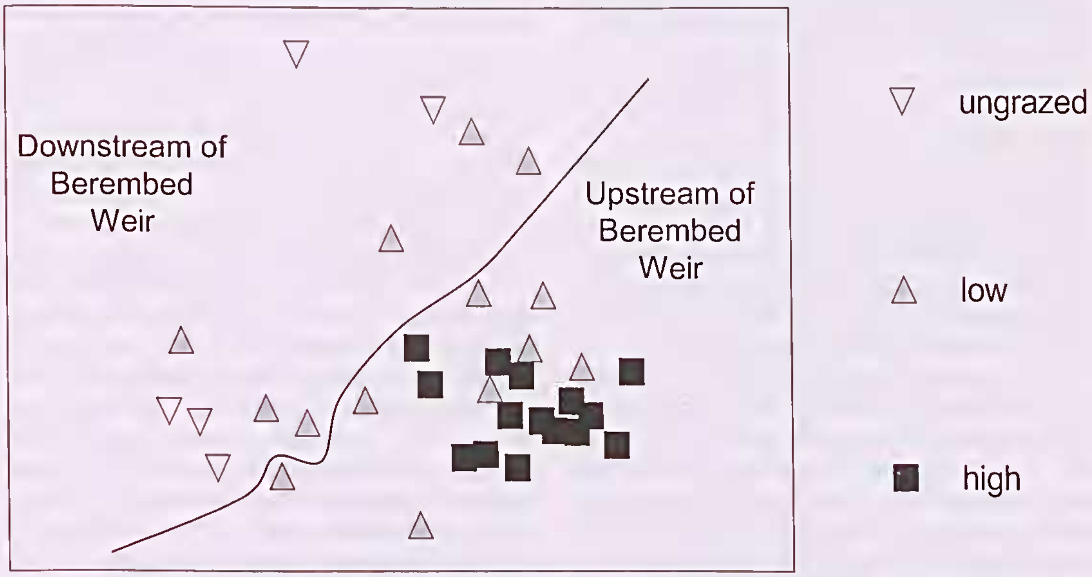

Fig 7. Non-metric multidimensional scaling plot of plant communities at 34 sites on the Murrumbidgee River according to grazing intensity. Stress=0.13. The line divides sites upstream and downstream of Berembed Weir.

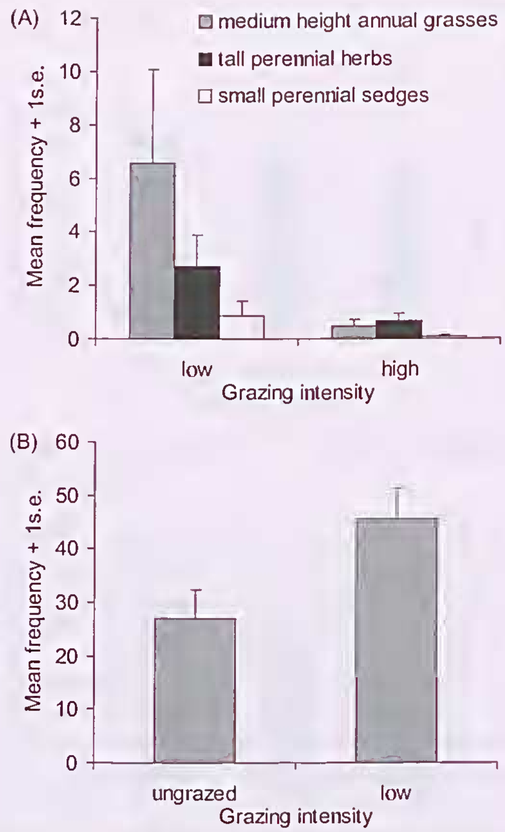

Fig 8. Mean (+1 s.e.) frequencies of (A) native plant functional groups upstream of Berembed Weir and (B) exotic annual grasses downstream of Berembed Weir at sites differing in grazing intensity on the Murrumbidgee River.

example, the indicators of riparian condition related to canopy cover, and bird species which mainly respond to canopy cover, are more likely to be influenced by past clearing associated with intensification of grazing than with current densities of stock. On the other hand, frog and plant communities, while likely to have been affected by past land management practices in terms of loss of species and invasion by exotics, are likely to also be responding to current grazing intensities.

Since grazing stock at high intensities necessitates some clearing of the riparian forest (to provide sufficient feed), it is not really necessary to separate past and current effects of grazing to demonstrate that, as shown here, grazing clearly has negative impacts on riparian condition and biodiversity. While many studies have concluded that grazing generally has negative impacts on riparian ecosystems (Elmore 1992; Armour et al. 1994; Fleischner 1994; Trimble & Mendel 1995; Larsen et al. 1998; Belsky et al. 1999), this study has demonstrated these impacts over large spatial scales and across a variety of biodiversity and functional measures within one ecosystem.

While grazing by domestic stock has clearly had major impacts on the condition and biodiversity of riparian zones, another major factor to consider is the influence of changed flooding regimes. The Murrumbidgee River is dammed upstream to provide water for irrigation in summer, and large off-takes below Berembed Weir provide water to irrigation areas. As a result, the seasonality of high flows and flooding events on the river, particularly upstream of Berembed Weir, has switched from predominantly winter-spring to predominantly summer (Ebsary 1994) and the extent and duration of flooding has approximately halved (Page et al. 2005). Downstream of Berembed Weir the seasonality of flooding has changed less but the volume of water has been greatly reduced (Page et al. 2005). These changes are likely to have particularly influenced wetlands, understorey plants and recruitment of river red gums, which are dependent on flooding (e.g. Dexter 1978; Young et al. 2001). These alterations to flows are likely to have exacerbated the impacts of grazing (e.g. Meeson et al. 2002).

Management implications: While it is clear that grazing has had significant impacts on riparian function and biodiversity, it is not clear how these impacts can be reversed to restore riparian river red gum habitats. The fact that grazing impacts encompass both current grazing intensities and past land management practices, and the fact that flooding regimes have also been greatly altered in these rivers, suggests that removal of grazing by itself is unlikely to lead to full restoration of riparian function and biodiversity.

Given the evidence of higher condition scores in ungrazed sites, there is possibly some potential for restoration of riparian habitats with removal of grazing. However, removal of grazing may not lead to restoration of riparian biodiversity, particularly if important components of the ecosystem have been lost. For example, Spooner et al. (2002) found that recruitment of shrubs was poor in fenced remnant grassy woodlands, perhaps due to a lack of seed sources. Kenny (2003) found that plant communities showed little response to 10 years of grazing exclusion in river red gum forests, possibly due to a lack of recruitment potential or to strong competition from dense river red gums. However, Thompson et al. (2002) found that birds in the upper Murrumbidgee Catchment showed some recovery within 10-15 years in response to restoration of riparian areas in the form of fencing and planting of trees and shrubs. Achieving full restoration of riparian function and biodiversity may require not only fencing to exclude stock or significantly reduce stocking rates, but also replanting of trees, shrubs and understorey, as well as on-going control of exotic species (Jansen & Robertson 2001a) and restoration of more natural flooding regimes (Robertson et al. 2001; Young et al. 2001).

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